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SAFETY HAZARD CLASSIFICATION OF WATER-WET EXPLOSIVES

DARRELL KITE, JR.

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FEBRUARY [illegible]

PICATINNY ARSENAL
DOVER, NEW JERSEY

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TECHNICAL REPORT 3223

SAFETY HAZARD CLASSIFICATION OF WATER - WET EXPLOSIVES

DARRELL KITE, JR.

AMC 4110.16.3053.12
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AMC 4110.16.2140.1.01.53

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PICATINNY ARSENAL
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BY

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SUMMARY

The purpose of this investigation was to determine the proper safety hazard classification of in-process water-wet explosives at the manufacturing plant. Eighteen water-wet explosives were studied to determine whether they could support detonations. Of the 18 explosives tested, 15 sustained detonations when "saturated" with water. ("Saturated" in this instance is defined as the condition wherein the spaces between the loosely packed explosive granules or crystals are completely occupied by water.) These 15 explosives are:

RDX Class A
RDX Class B
RDX Class C
RDX Class D
RDX Class E
RDX Class F
RDX Class G

Composition C-4
Composition A-3

PBX 9404
PBX Type B
PBX 9010

HMX Class A
HMX Class C
HMX Class D
HMX Class F

The other three explosives did not sustain detonations under saturated conditions. However, they did sustain detonations at these water levels:

PBX-N3 @ 25% water
HMX Class B @ 44% water
HMX Class E @ 40% water

All explosives tested were found to sustain detonations at water levels that could be encountered in manufacturing operations following the filtering operation. Therefore, the filtered explosives should be assigned a safety hazard classification of Class 9.

CONCLUSIONS

All materials tested sustained detonations at high water contents. As handled in manufacturing plants, after filtering, these explosives should be assigned a safety hazard classification of Class 9. These explosives are:

RDX Class A
RDX Class C
RDX Class D
RDX Class E
RDX Class F
RDX Class G

HMX Class A
HMX Class B
HMX Class C
HMX Class D
HMX Class E
HMX Class F

Composition C-4
Composition A-3

PBX 9404
PBX Type B
PBX 9010
PBX-N3

RECOMMENDATIONS

Since all explosives tested under this program sustained detonations at high water contents, the filtered explosives (as handled in manufacturing operations) should be considered Class 9.

BACKGROUND

At U. S. Army Materiel Command explosive manufacturing works, protection is afforded to personnel and facilities by limiting the amount of explosives that may be present at a given location under various conditions. Factors considered are: distance to inhabited buildings, type of barricades, interline distance, dangers inherent in the specific explosives involved and other safety factors. Information regarding the quantity limitations of explosives is contained in Section 17 of the Ordnance Safety Manual (Reference 1).

At Holston Army Ammunition Plant (HAAP), Kingsport, Tennessee various explosives are filtered from a water slurry to yield water-wet explosives. In the absence of data that would establish the hazard of these filtered materials, they have been considered to be Class 9 explosives -- mass-detonating, bulk explosives. This safety hazard classification limits the amount of explosives that can be in operating buildings. This result is a limitation on manufacturing efficiency and increased cost of explosives.

Since manufacturing operations could be more efficiently performed if the explosive hazard classification could be safely reduced, Picatinny Arsenal undertook to establish the safety hazard classification of various water-wet explosives.

STUDY

Test Vehicle

The test procedure used in this study was designed to show whether the explosives are mass detonatable. As defined in the Ordnance Safety Manual, mass detonation is: "Detonation of separated quantities of explosives or ammunition occurring so nearly at the same time that the effect on the surroundings is the same as if the several quantities were not separated." For the purpose of this study it was assumed that any bulk material capable of sustaining a detonation is potentially mass detonating and therefore should be assigned a safety hazard classification of Class 9.

In this investigation the water-wet explosives were loaded into plexiglas tubes, initiated and observed by means of a framing camera to determine whether detonations occurred, and to establish the approximate rate of detonation. Plexiglas tubes were chosen as containers because they enable a visual check on the quality of the loading operation.

A schematic of the test vehicle is shown in Figure 1. All tubes were 1-3/4 inches inside diameter. Wall thickness of the tubes was either 1/8 or 1/4 inch. Explosive column length was about 10 inches in some cases and about 20 inches in others. The booster usually was one 33-gram tetryl pellet. However, 40-grain RDX wafers were used on occasion.

Loading Methods

The materials loaded were bulk explosives procured from HAAP. These were granular explosives taken from the production line following the filtering operation. The materials were not dried prior to shipment. At Picatinny Arsenal, the explosives were water-washed and loaded into the test vehicles. The loading methods used are:

Method A - Water Displacement Method -- The washed explosives were covered with water. The test vehicles were filled with water. Wet explosives were loaded into the test vehicles, displacing the water. Excess water was removed from the top of the explosive column, leaving a column consisting essentially of explosive and water. This method was used when it was desired to test explosives, of medium-to-large granulations, at maximum water contents.

Method B - Saturated Explosive Method -- The explosives were washed and excess water filtered off or allowed to drain off leaving an explosive paste. The paste (consisting of wet RDX or HMX of small particle size) was loaded into the test vehicles. Excess water rose to the top of the column and was removed, leaving a column consisting essentially of explosive and water. This method was used to load explosives of fine granulation at high water levels. Method A was not suitable for use with explosives having fine granulation because they settled out too slowly and formed non-uniform explosive columns.

Method C - Partially Dry Method -- The washed explosive was retained on filter cloth. Air was drawn through to partially dry the explosive, which was then loaded into the test vehicles. Using this loading method, air was present. This method was used when it was desired to test explosives at less than maximum water levels.

Determination of Explosive Water Content

Two methods were used for determining the water content of the wet explosives being tested. They are:

Method I - Direct Calculation -- This method is based on the simultaneous solution of two equations. The equations are :

$$We + Ww = Wt \text{ and } \frac{We}{De} + \frac{Ww}{Dw} = Vt$$

We = Weight of explosive
Ww = Weight of water
Wt = Weight of explosive + water
De = Density of explosive
Dw = Density of water
Vt = Volume of explosive column

In this method, the volume and total weight of the explosive-water mixtures contained in the test vehicle are determined. Then for those mixtures which contain no air, and for which the explosive density is known, the amount of water present is calculated. Since Wt, De, Dw and Vt are known, We and Ww can be calculated. This method was used to determine the amount of water present in RDX-water mixtures and HMX-water mixtures that contained no air. The densities used were:

RDX, 1.82 grams per cc
HMX, 1.9 grams per cc

In actual practice, percent water vs. bulk density curves were constructed and used to determine water present in the RDX-water and HMX-water mixtures.

Method II - Moisture by Analogy -- Method I is not suitable for determining the amount of water present in those explosives mixtures containing air or those mixtures in which the density of the explosive is unknown. In these cases, the determinations were made by analogy. Two or more test vehicles were loaded in a similar manner. One or more of the vehicles were then analyzed to determine the amount of water present. The amount of water present in the dried vehicle was assumed to be about the same as in the vehicle that was test fired. A rough check on this could be made by determining the bulk density of the wet explosives in the dried and fired vehicles; the assumption being that if the bulk densities were the same, the amount of water present was likely to be about the same. In general, there was good agreement between the two bulk densities.

The percent of water present in the RDX test vehicles is reported in Table 1. The water present in the fired vehicles was determined by Method I. There is one exception. In the case of RDX Class E, Shot 16A, there is a significant difference between the calculated amount of water present and that determined by analogy. The calculated amount of water present is 46%, by analogy the amount is 39%. In this case, some air may have been present -- causing the amount of water present to appear high when it was calculated. The probable correct value is 39%.

The percent of water present in the HMX test vehicles is reported in Table 2. The water present in the fired vehicles was determined by Method I.

The percent of water present in the explosive compositions is reported in Table 3. The amount of water present in the fired vehicles was determined by Method II.

Determination of Approximate Rate of Detonation

Detonation or lack of detonation was determined by two methods. One was simply by observation of the test site to determine if the test vehicle and holding stanchion were destroyed. In a second method, a series of photographs were made by means of a framing camera; the movement of the wavefront through the explosive could be followed by observation of these photographs.

Figure 2 is a series of photographs taken by the framing camera and shows the progress of a detonation wave. In this case, HMX Class E, containing 58% water was initiated by a 33-gram tetryl pellet. It can be seen that the explosion died out almost immediately. The series of photographs in Figure 3 shows the progress of a detonation through PBX-N3 that had a 28% water content. The photographs show that the detonation died out after it had traveled a short distance through the wet explosive column. Since the detonation died out before it passed through the entire length of the column, it is concluded that under the test conditions used, PBX-N3 will not sustain a detonation at the 28% water level.

Figure 4 is a series of photographs showing the progress of a detonation wave through HMX Class E containing 40% water. It is seen that the column detonated throughout its length. Shown in back of the test vehicle is a graph having alternating dark and light lines two inches wide. Since it is known that 4.27×10^{-6} seconds elapsed between picture frames, the approximate velocity of the detonation wave can be calculated. In this case, the detonation front moved about 12 inches in 10 time-intervals -- in 4.27×10^{-5} seconds. The detonation front moved at a rate of 2.81×10^{5} inches per second (or 7,150 meters per second). All reported detonation velocities were approximated by this method.

Effect of Booster

Two different attempts were made to detonate two PBX 9404 charges containing 34% water. The known difference between the two tests is that in one case the booster used was a 40-grain RDX wafer; in the other case the booster was a 33-gram tetryl pellet. When the 40-grain RDX wafer was used, the PBX 9404 failed to detonate; when the 33-gram tetryl pellet was used, the PBX 9404 detonated. The test was not repeated and therefore the data is limited; however, as would be expected, the importance of donor selection is indicated. It appears that under these test conditions the wet PBX 9404 will sustain a detonation once it has been strongly initiated. Apparently the 40-grain RDX wafer was not powerful enough to initiate the wet explosive.

Effect of Explosive Confinement

The diameter of an explosive column is in some cases an important factor in determining if a detonation will be sustained. In general, for a given explosive and set of test conditions in which the diameter of the explosive column is varied, there is a critical diameter below which a detonation will not be sustained. This critical diameter can generally be decreased by increasing the strength of the containing wall. In the case of PBX-N3, at the 25% moisture level, the explosive column failed to sustain a detonation when contained by a plexiglas tube having 1/8-inch-thick walls. However, in a similar test when the wall thickness was increased to 1/4-inch, a detonation was sustained. Again, this is only indicative since the data is limited.

Classification of Explosives Tested

The data generated under this study pertinent to establishing the safety hazard classification of water-wet explosives is in Tables 1-3. In evaluating this data it has been considered that bulk water-wet material capable of sustaining a detonation is potentially mass detonatable and consequently should be assigned a safety hazard classification of Class 9.

Using this criterion, the following 15 materials should be classified Class 9 since detonations were sustained in mixtures which consisted essentially of explosive and water. The explosives and water content are:

Explosive	Percent Water
HMX Class A	22
HMX Class C	19
HMX Class D	26
HMX Class F	25
RDX Class A	27
RDX Class C	21
RDX Class D	24
RDX Class E	39
RDX Class F	23
RDX Class G	23
Composition C-4	20
Composition A-3	31
PBX 9404	34
PBX Type B	35
PBX 9110	36

Three other explosives were tested: PBX-N3, HMX Class B and HMX Class E. It was found that PBX-N3 sustained a detonation at a 25% water level. In other tests, in which lighter walled test vehicles were used, PBX-N3 failed to sustain detonations at 25% and 28% water levels. HMX Class B sustained a detonation at the 44% water level; it failed to do so at the 49% level. HMX Class E supported a detonation at the 40% water level; it failed to do so at the 58% level. Thus, water levels were established at which these explosives failed to sustain detonations. However, these tests were not adequate to show that these explosives will not sustain detonations at the higher moisture levels. For example, if they were to be confined in tubes stronger than the plexiglas tubes used or if tubes of greater diameter were to be used, perhaps detonations would be sustained. In any case, it was found that they sustain detonations at water levels generally higher than those of filtered explosives. For these reasons, these explosives should be considered Class 9.

Formulation of the explosive compositions is given in Table 4.

REFERENCE

1. Ordnance Safety Manual, ORD M7-224, Ordnance Corps, Department of the Army, 1951.

APPENDICES

APPENDIX A

TABLES

TABLE 1

RDX TEST DATA

Explosive	Shot Number	Loading Method	Wall Thickness (inches)	Percent Water			Wet Bulk Density lb/ft^3		Booster (gram tetryl)	Approximate Detonation Velocity Meters/sec
				Fired Vehicle	Dried Vehicle		Fired Vehicle	Dried Vehicle		
				Calculated	Calculated	Analytical				
RDX Class A	3	**	1/8	27	28	29	92.7	92.3	33	7,700
RDX Class C	2A	*	1/8	21	21	19	97	96.6	33	7,700
RDX Class D	15A	*	1/4	24	23	22	95	95.6	33	7,800
RDX Class E	16A	**	1/4	46	46	39	82.3	82.5	33	6,400
	9A	**	1/4	37	36	36	87.5	86.6	33	6,900
RDX Class F	17A	*	1/4	23	21	23	95.8	96.4	33	7,900
RDX Class G	18A	*	1/4	23	22	1[illegible]	95.4	96	33	8,000

* Loaded by water displacement method
** Loaded by saturated explosive method

Unless otherwise specified, data refers to fired vehicle

TABLE 2

HMX TEST DATA

Explosive	Shot Number	Loading Method	Wall Thickness (inches)	Percent Water			Wet Bulk Density lb/ft^3		Booster (gram tetryl)	Approximate Detonation Velocity Meters/sec
				Fired Vehicle	Dried Vehicle					
				Calculated	Calculated	Analytical	Fired Vehicle	Dried Vehicle		
HMX Class A	21A	*	1/4	22	20	20	98.6	100.2	33	7,900
HMX Class B	10A	**	1/8	49	47	47	82.2	83.6	33	None
	5A	**	1/8	44	46	44	84.9	84	33	6,400
HMX Class C	19A	*	1/4	19	19	18	101	101.5	33	7,900
HMX Class D	22A	*	1/4	26	28	24	96.5	95	33	7,400
HMX Class E	11A	**	1/8	58	54	54	77.9	79.6	33	None
	7A	**	1/8	40	40	40	87.4	87.4	33	7,100
HMX Class F	20A	*	1/4	25	24	22	96.8	97.3	33	7,700

* Loaded by water displacement method
** Loaded by saturated explosive method

Unless otherwise specified, data refers to fired vehicle

TABLE 3

TEST DATA ON EXPLOSIVE COMPOSITION

Explosive	Shot Number	Loading Method	Wall Thickness (inches)	Percent Water		Wet Bulk Density lb/ft^3		Booster	Approximate Detonation Velocity Meters/sec
				Fired Vehicle by Analogy	Dried Vehicle Analytical	Fired Vehicle	Dried Vehicle		
Composition C-4	12	*	1/8	20	20	89.2	89.5	33 gram tetryl	6,800
Composition A-3	13	**	1/8	31	31	83	83.5	33 gram tetryl	6,500
PBX 9404	22	*	1/8	34	34	90.3	90.	40 grain RDX wafer	None
	18	*	1/8	34	34	89.5	90.5	33 gram tetryl	5,800
PBX Type B	23	*	1/8	35	35	84.7	84.3	40 grain RDX wafer	6,800
PBX 9010	11	*	1/8	36	36	86.5	87.8	33 gram tetryl	6,500
PBX N-3	14A	***	1/4	25	25	53.9	54.4	33 gram tetryl	2,900
	12A	***	1/8	25	25	53.4	54.7	33 gram tetryl	None
	1A	***	1/8	28	28	55	54.4	33 gram tetryl	None

* Loaded by water displacement method
** Loaded by saturated explosive method
*** Loaded by partially dry method

Unless otherwise specified, data refers to fired vehicle

TABLE 4

FORMULATION OF EXPLOSIVE COMPOSITIONS

Explosive	Nominal Composition	Percent
Composition C-4	RDX	90.5
	Polyisobutylene Binder	9.5
Composition A-3	RDX	91
	Wax	9
PBX 9404	HMX	94
	Nitrocellulose: Tris-beta chloroethyl phosphate binder	5.9
	Diphenylamine	0.1
PBX Type B	RDX	90
	Polystyrene binder	10
PBX 9010	RDX	90
	Kel-F binder	10
PBX-N3	(Classified)	

APPENDIX B

FIGURES

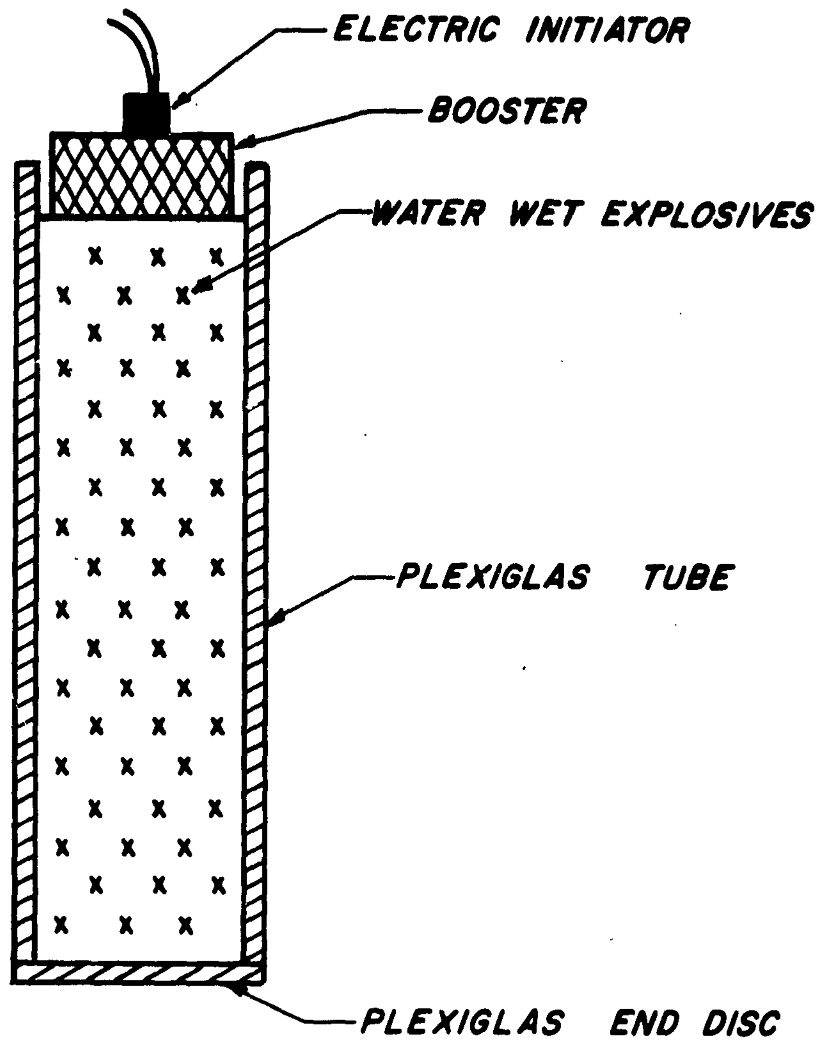
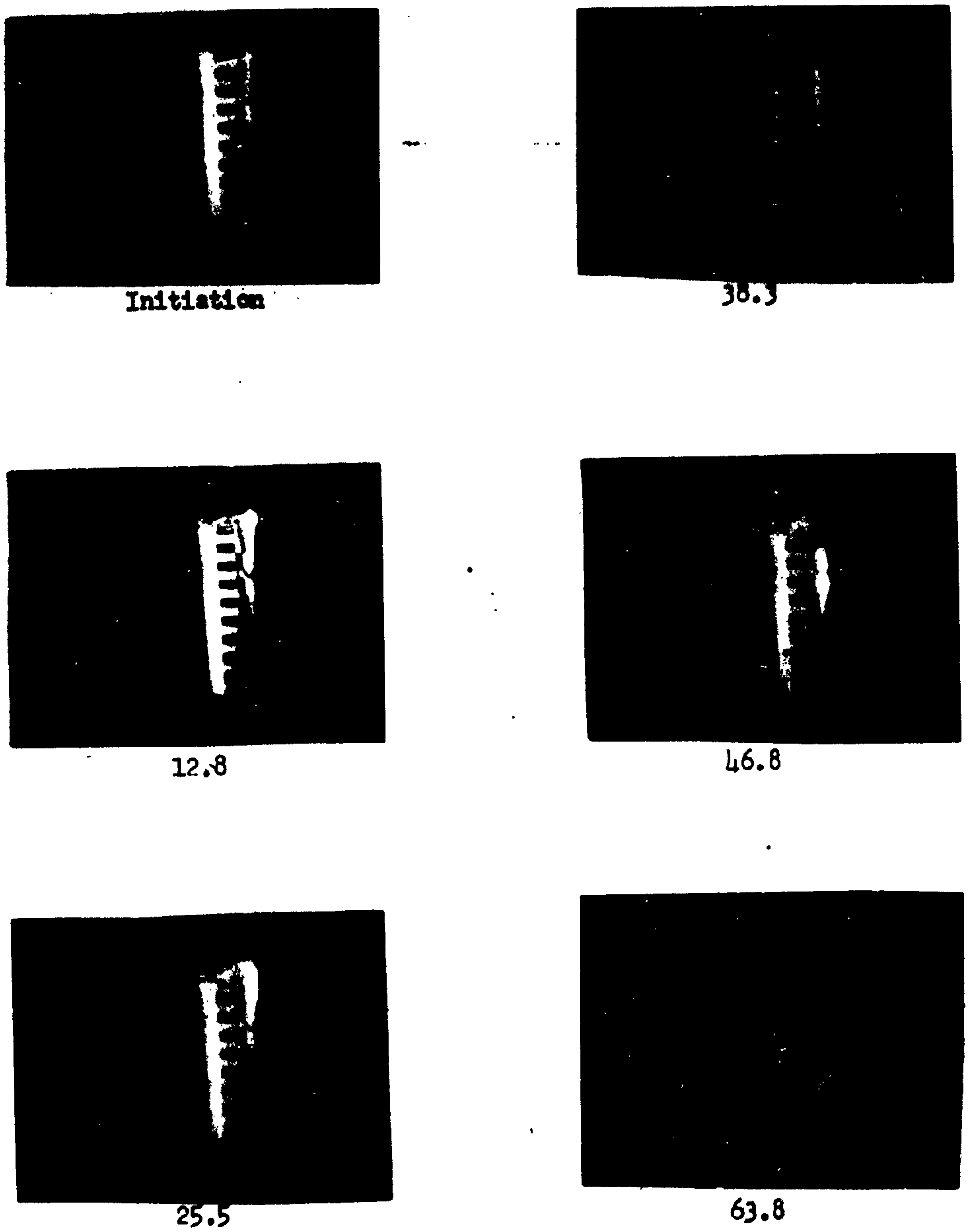


Figure 1

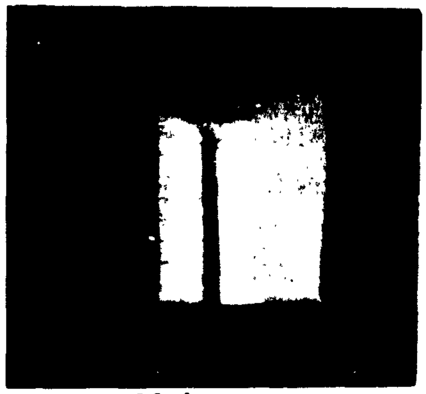
SCHEMATIC OF TEST VEHICLE



Time after initiation is shown in microseconds

Figure 2
Attempted Detonation of HMX Containing 58% Water


Initiation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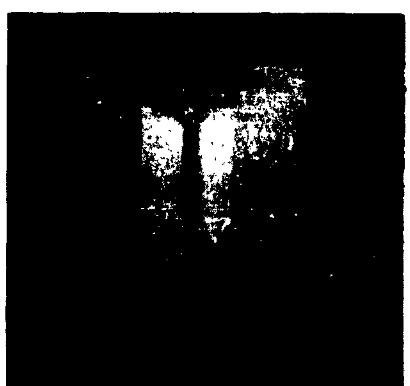
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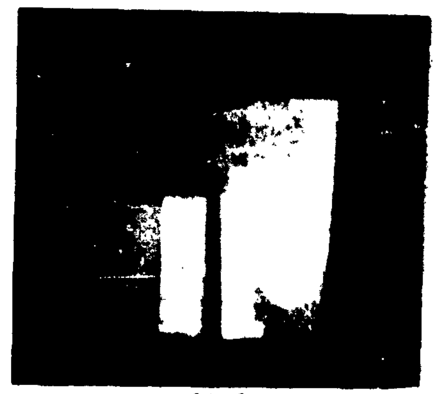
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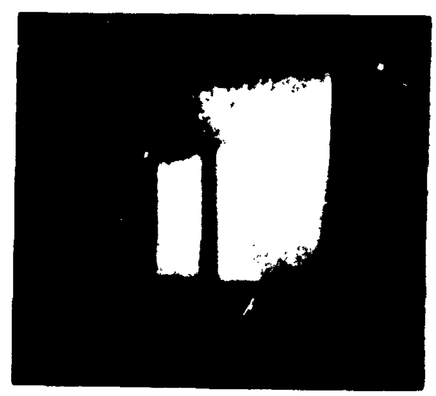
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Time after initiation is shown in microseconds

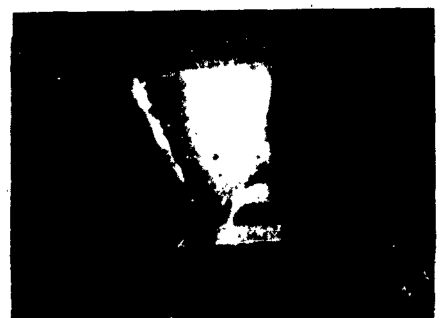
Figure 3
Attempted Detonation of PBX-N3 Containing 28% Water

Initiation

8.5

21.4

34



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59.8

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Figure 4
Detonation of HMX Class E Containing 40% Water

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11 SUPPLEMENTARY NOTES	12 SPONSORING MILITARY ACTIVITY Picatinny Arsenal U. S. Army Munitions Command Dover, New Jersey

13 ABSTRACT

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All explosives tested were found to sustain detonations at water levels that could be encountered in manufacturing operations following the filtering operation. Therefore, the filtered explosives should be assigned a safety hazard classification of Class 9.

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Security Classification

KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
RDX						
Composition C-4 and A-3						
PBX						
HMX						
Water-wet explosives						
Mass detonating						
Safety hazard						
Manufacturing cost						

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